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ABSTRACT

This paper reports a study which attempted to generalize earlier results obtained by Eastman to another mathematical content area. Two hundred eight ninth-grade algebra students were randomly assigned to one of the two treatments. The figural-inductive treatment presented concepts of logic through the use of Euler diagrams in an inductive mode; the symbolic-deductive mode presented the same concepts in a symbolic and deductive mode. Aptitudes of subjects were measured using tests of necessary arithmetical operations, abstract reasoning, inference, and figure classification. After treatment, achievement was measured using an experimenter-constructed test. A retention test (parallel to the posttest) was administered one week later. The data from criterion measures of learning and retention did not support the hypothesis of a significant Aptitude Treatment Interaction (ATI) between selected aptitude measures and the two treatment modes. Discussion of four apparent and significant problems in the area of ATI research is presented. (Author/SD)

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Interaction Between Structure of Intellect Factors and Two Methods of Presenting Concepts of Logic

Abstract

This paper reports a study which attempted to generalize earlier results obtained by Eastman to another mathematical content area. The Ss for the experiment, 208 ninth grade algebra students, were randomly assigned to one of the two treatments. The figural-inductive treatment presented concepts of logic through the use of Euler diagrams in an inductive mode; the symbolic-deductive mode presented the same concepts in a symbolic and deductive mode. The data from criterion measures of learning and retention did not support the hypothesis of a significant ATI between selected aptitude measures and the two treatment modes. Discussion of four apparent and significant problems in the area of ATI research is presented.

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INTERACTION BETWEEN STRUCTURE OF INTELLECT FACTORS AND TWO METHODS OF PRESENTING CONCEPTS OF LOGIC

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A number of psychologists--Bloom, Cronbach, Gagne, Glaser, and others--have suggested that no single instructional process or strategy will provide an optimal learning opportunity for all students concerned with achieving a common set of educational objectives. Cronbach (1957) suggested that researchers should give direct attention to this problem by conducting experiments for the sole purpose of isolating interactions between personological variables and instructional treatments. Prior research had dealt with such observed interactions more as an artifact of the results rather than the major purpose of the research. The experimental objectives of such proposed research would be to isolate aptitude by treatment interactions (ATI's).

The ultimate educational purpose of ATI research is to provide a means for accommodating for individual differences among learners. In an educational setting a decision-making process for assigning learners to different instructional treatments would be required. Decision making (e.g., placement of students) would require a priori knowledge of the existence of interactions between measurable personological variables and instructional treatments as evidenced by educationally relevant criterion variables, such as learning, retention, and transfer. The question of whether the interaction is ordinal or disordinal is also relevant to decision making in the educational process.

Given that the relative cost of two treatments are comparable, then necessary for student placement decisions, for example, is the existence of a personological variable (or variables) and associated measure(s) such that learners who score low on measures of the variable achieve high after learning from an instructional treatment T_A and low after learning from an instructional treatment T_B. On the other hand learners who score high on a measure of this variable would achieve high after learning from treatment T_B and low after learning from treatment T_A. The graphical representation of this type of situation would be as depicted in Figure 1. Figure 1 illustrates a disordinal

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Insert Figure 1 here

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interaction between a personological variable and two treatments T_A and T_B. Learners whose scores fall to the left of the point on the abscissa below the intersection of the lines would be assigned to treatment T_A, while others would be assigned to treatment T_B. A situation in which an ordinal interaction would be important in the decision making process is if in Figure 1, T_B is uniformly superior for all students in the range of scores, but <u>its cost per pupil</u> is high compared to T_A. The combination of cost and treatment effects could force placement decisions comparable to those suggested above. This discussion can be generalized to two or more personological variables; in this case the lines in Figure 1 become planes or hyperplanes.

Soloman (1972) labels the ATI model discussed above as a preferential model. It is classified as preferential because the treatment by which learners are most successful is that one preferred by the learner--preferred in the sense that it capitalizes on an observable aptitude. Soloman identifies and discusses two other models for ATI research. A compensatory model, in which the treatment is designed to compensate for an observable deficiency of the

learner, would have a graph in which the slopes of the graphs for T_A and T_B in Figure 1 would be equal in magnitude by opposite in algebraic sign. Soloman (1972) notes: Apparently, the treatments "compensate for each learner's deficiency by providing the mode of presentation that the learner cannot provide for himself." (Soloman, 1972, p. 333) A remedial model would involve treatments designed to remediate on learners' observed weaknesses.

Results of ATI research to date have been equivocal insofar as giving support to the general ATI hypothesis. That is, evidence is scant that learners can be assigned to one of several possible instructional treatments based on the performance on certain personological (aptitude) measures in such a way that their learning is optimal. Discussion of some apparent difficulties in ATI research--including aptitude measurement and theory, criterion variables, and analysis procedures--as well as the report of an ATI investigation is included in this paper.

Behr (1970), Eastman (1972) and Behr and Eastman (1973) have reported work on attempts to isolate interactions between cognitive aptitude variables and instructional treatments. In these studies the selection of aptitude variables (and tests) was based on the Guilford (1967) Structure-of-the-Intellect model. Results of these studies do not support Guilford's claim of separate and distinct mental factors. Behr and Eastman (1973) used two tests each for Guilford's factors of CFR, CFT, CMS, and CMU. A factor analysis of the data collapsed the four hypothesized factors to two, one on the F (figural) dimension, and one on the M (semantic) dimension. Eastman (1972) found a correlation of .52 between test scores for two Structure-of-the-Intellect factors (CMS and CFR) purported by Guilford to be distinct factors--one a <u>figural factor</u>, the a <u>semantic factor</u>. These results cause concern about the validity and reliability of theories of mental aptitudes and raise serious doubts about

relying on current mental aptitude theories for the isolation of ATI's. Behr and Eastman (1973) have appealed for basic research in aptitude theory which might be subject matter specific. For example it might be fruitful to attempt the development of a theory of mathematical aptitudes.

Another area of concern, but one for which a more immediate solution is apparent, is the question of appropriate analysis techniques for ATI studies. It appears that most studies reviewed by Bracht (1970) used standard analysis of variance techniques. Later studies by Carry (1968), Webb (1971), Eastman (1972), and Behr and Eastman (1973) used a homogeneity of regression analysis as specified by Bottenberg and Ward (1963). Borich (1971) and Borich and Wunderlich (1973) discussed an analysis technique proposed by Johnson and Neyman (1936), and presented a computer program for computation of the data in an ATI study. The Johnson-Neyman technique has an advantage over the Bottenberg and Ward approach because in addition to testing the hypothesis of equal regression slopes across treatments, regions of significant and nonsignificant treatment interactions when the equal slopes hypothesis is rejected, are also determined. The use of the Johnson-Neyman technique is supported by the authors and was used in the analysis of the data of the study herein reported and is discussed further in the results section of this paper.

The Study

The study reported in this paper is directly related to the work of Eastman (1972), which was a continuation of work begun by Carry (1968) and Webb (1971). Eastman obtained a significant interaction when the criterion measure of transfer was regressed on factors of general reasoning and spatial visualization. In his study the Necessary Arithmetic Operations (NAO) test and the Abstract Reasoning test of the Differential Aptitude Test Battery (DAT) were used to measure these aptitudes, respectively. Two treatments, one graphical and the other analytical,

were used to present methods for finding solution sets of quadratic inequalities. In the graphical treatment, concepts were presented in a figural-inductive mode. In the analytical treatment, concepts were presented in a symbolic-deductive mode. Eastman observed that factor analytic studies indicated that the measure for spatial visualization used by Carry and Webb (paper folding) had factor loadings on deduction. Conjecturing that the problem of deductive versus inductive presentation of the learning material might have been a confounding variable in the Carry and Webb studies, Eastman selected a different measure for spatial visualization, revised the instructional treatments to reflect a figural-inductive mode and a symbolic-deductive mode of presentation and was successful in isolating an interaction.

The present study was an attempt to generalize the results of Eastman to another mathematical content area. Two instructional treatments were written by the authors to present basic logical inference patterns and common logical fallacies. Three inference patterns were presented--modus ponens, modus tollens and the law of hypothetical syllogism. The two treatments can be characterized as symbolic-deductive and figural-inductive.

In the figural-inductive treatment the concept of Euler diagrams was introduced and used to determine whether a conclusion was possible according to one of the three inference patterns. The use of Euler diagrams reflects the figural nature of the treatment. The inductive nature of the treatment was reflected by the fact that Ss learned to analyze premises via numerous examples without being given--either symbolically or verbally--a statement of the inference patterns. By contrast the deductive nature of the other treatment was reflected by the fact that the inference patterns were given to Ss as <u>rules</u> prior to any exemplification of the rules, and were given in symbolic

form. The symbolic nature of the treatment was further reflected by the fact that Ss were taught to translate verbal premises to symbolic forms, whereas in the figural-inductive treatment Ss translated verbal premises into Euler diagrams. Figure 2 presents an example to illustrate the treatment differences.

Insert Figure 2 here

The Necessary Arithmetic Operations (NAO) test and the Abstract Reasoning test were used as measures of the symbolic-deductive aptitude and the figural-inductive aptitude, respectively. They were selected because of their previous success in predicting the treatments in the Eastman (1972) study. Two additional tests, Inference Test and the Figure Classification Test were selected; the former was hypothesized to preduct the symbolic-deduction treatment and the latter the figural inductive treatment. The Inference Test was selected because of its classification by French (1963) as a test for deduction. The Figure Classification Test was selected because the investigators felt that the skill required to solve the problems correctly on that test was very similar to the skill required in solving the logic problems on the criterion used in this study.

Method

The subjects for the experiment were 208 ninth grade students enrolled in ninth grade algebra in a suburban Chicago high school. After being tested on the mental factors, Ss were randomly assigned to one of the two treatment groups. The figural-inductive (F) group studied the mathematical concepts from the figural-inductive programmed presentation and the symbolic-deductive (S) group from the symbolic-deductive programmed presentation. Subjects were limited to two forty-five minute class periods for studying the programmed

units. Learning and retention tests were administered one day and two weeks respectively following the last study session. The learning and retention tests were parallel forms. Items on each were of two kinds: fifteen of the twenty test items consisted of meaningful verbal premises, and five consisted of nonsense verbal premises. The learning and retention tests required the Ss to demonstrate that they had learned and retained the material presented in the programmed treatments. Transfer to unfamiliar situations was not required.

There were four criterion tests: (1) meaningful verbal premises, Learning Part I; (2) nonsense verbal premises, Learning Part II; (3) Total Learning Test; and (4) Retention test. The sequence of hypotheses for the orderly investigation of the data for each criterion as provided by Borich (1973) is as follows:

H_1: Homogeneity of variance for the criterion across groups. If H_1 is rejected, additional hypotheses cannot be meaningfully tested.

H_2: Homogeneity of group regressions. If H_2 is rejected, H_4 is tenable and becomes the final hypothesis; if not, H_3 is tenable.

H_3: Equality of intercept. If H_3 is rejected, group means differ significantly.

H_4: Regions of significance for the interaction. If H_4 is rejected, no regions exist for which group regressions are significantly different but if H_4 is not rejected regions exist as conic sections which can take the form of either an ellipse or hyperbola. There may be only one region of significance or data may be found within only one region. The Johnson-Neyman region describes an area in terms of the predictor variables for which there are heterogeneous group regressions and for which individual or mean values on the predictor variables fall within the region of significance.

The .05 level of significance was selected for all tests.

Results

Table 1 and 2 report the descriptive statistics for all tests administered to the Ss. The results of Table 1 indicate that learning and retention scores were not significantly different between groups. The test scores indicate that

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Insert Tables 1 and 2 here

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significant learning occurred and that there were no "topping out" effects.

Table 3 presents the correlations between each aptitude measure and the criterion measure for each group. Correlations are included for each of the four criteria used (Total Learning score, Learning Part I, Learning Part II, and Retention score).

Insert Table 3 here

There were two measures for the figural-inductive aptitude and two measures for the symbolic-deductive aptitude; therefore, there were four aptitude combinations which were hypothesized as interactive with each of the four criterion tests. Thus, sixteen tests of homogeneity of regression were conducted. In no case was the hypothesis of homogeneity of regression rejected. F-values and probability values are listed in Table 4 for each test. Homogeneity of variance between groups was not rejected in all cases.

Insert Table 4 here

In no case was the hypothesis of homogeneity of regression rejected, but one can observe from Table 4 that the F-value for the Learning Part II test seems to be generally higher than for the other criteria. This tends to support

earlier hypotheses by Behr and Eastman (1973) that aptitude treatment interaction will more likely be isolated using criterion measures other than that of immediate learning. In this case the items on Part II were nonsense items, material which was not studied in the learning material. Since H_2 was not rejected for any of the sixteen tests of homogeneity of regression, H_4 was in all cases untenable.

Discussion

The findings in this study do not give positive support to the general ATI hypotheses. The problem of correlations between aptitude test scores being unstable from one experimental population to another was again observed. A correlation of .26 between the factor tests for CMS and CFR was obtained in this experiment as opposed to .52 obtained by Eastman (1972). Also criterion measures which did not provide high level cognitive demands on the Ss may again explain the lack of success in obtaining an ATI. The investigators see a number of prominent problems emerging in the area of ATI research. These problems and some direction for future research on these problems are suggested below:

(1) What aptitudes (and associated measurement instruments) are appropriate for predicting achievement on mathematics learning material?

This problem is as old as the area of ATI research. Cronbach (1957) suggested the use of "nonstandard" aptitude measures which might measure more precisely the potential necessary for achievement in a particular mathematical area. Many investigators (including the authors) have chosen aptitude measures on the basis of the work of psychologists and general theories of human intelligence such as Guilford's (1967) work. These measures appear to be too complex. They apparently measure more than one particular aptitude and consequently when used in ATI studies do not predict success differentially across different modes of learning. It appears that a substantial effort needs to be made in the area of isolating aptitudes which are relevant to different areas

of mathematical achievement. This is a monumental task which will take considerable time and effort. Yet without it, these investigators see limited and incidental success in isolating aptitude treatment interactions.

(2) What type of criterion measures should be used?

This problem is also an old problem in ATI research. Many types of criterion measures have been used, including: (1) time to criterion; (2) learning test; (3) retention test; (4) transfer test, and (5) combinations of these. The investigators see some progress in this area, although only indications of appropriate measures have surfaced. For example, it appears from previous results of Behr (1970), Eastman (1972) and Eastman and Behr (1973) that criterion measures other than tests of immediate recall show greater promise for isolating an ATI. These investigations suggest that criterion measures which require more cognitively difficult tasks than immediate recall or computation have a higher probability of producing ATI's. The authors propose that transfer tests, tests of delayed retention, and tests which require the Ss to use higher levels of cognitive functioning are more appropriate criteria. Also of primary importance here is the reliability of the criterion measures. Reliability must be high in order for results to be valid.

(3) What type of analysis is appropriate in ATI studies?

This seems to be a question which has plagued ATI researchers. In many earlier studies univariate regression analysis or analysis of variance was used. It appears that more researchers are now using some form of multiple linear regression analysis with an accompanying test for homogeneity of regression. With the emergence of computer programs which will handle two independent (predictor) variables, such as the Borich and Wunderlich (1973) program, some stability in type of analysis should result. A most convenient

feature of the Johnson-Neyman computer program developed by Borich and Wunderlich (1973) is that it calculates the region of significance for data points following successful heterogeneity of regression tests.

(4) How long must instructional treatments be so that stable ATI's will be observed?

This problem is a practical problem and may in itself be one of the major reasons for lack of success in isolating ATI's. Few investigations have lasted over 2 or 3 class periods. Experiments designed to last 1 or 2 semesters are needed.

The authors are hopeful that this discussion of some of the problems which have been encountered will be of help to other researchers in this area. The general ATI hypotheses advanced by Cronbach (1957), the heuristic models supplied by Soloman, and the emergence of computer programs such as the Johnson-Neyman program produced by Borich and Wunderlich (1973) supply the theoretical background and a desirable tool for the statistical analysis of ATI studies. Need for investigations in the area designed to more clearly determine mathematical aptitudes and appropriate criterion variables, and with longer instructional treatment, still exists in order to make progress in answering questions of a general nature in ATI research.

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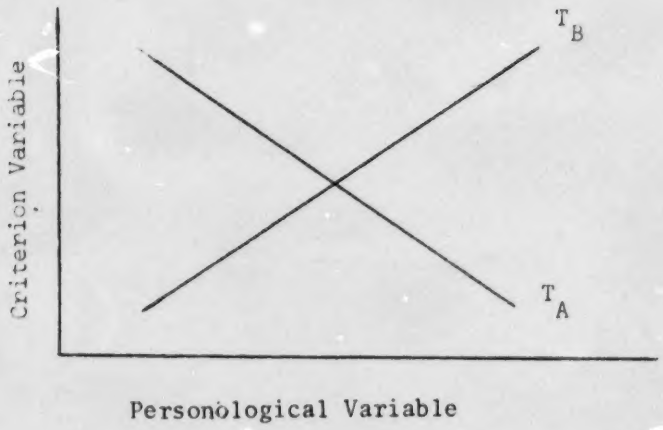

Figure 1

Regression Lines for Two Treatments Exhibiting a Disordinal Interaction

Figural-inductive

Determine the conclusion which follows from the following premises:

(1) If a boy is in ninth grade, then he likes to play football.

(2) Bill is in ninth grade.

Draw a diagram to represent premise (1).

F: People who like to play football.

G: 9th graders.

On the same diagram represent premise (2).

The dot represents Bill.

What is the conclusion which follows from the premises?

Answer:

Bill is a football player.

Figure 2

Example of Treatment Differences

Symbolic-deductive

Now let's see if we can draw any valid conclusions from the following two premises

(1) If a boy is in ninth grade, then he likes to play football.

(2) Bill is in ninth grade.

We can replace "If a boy is in ninth grade" by p and "he likes to play football" by q.

Then the two premises can be represented as follows:

(1) $p \rightarrow q$ (or if p, then q)

(2) p.

Hence using rule 1, we can conclude

Answer:

q: Bill likes to play football.

Figure 2--Continued

Example of Treatment Differences

Table 1

Means and Standard Deviations of Pretests and Posttests for the Figural and Symbolic Groups[a]

Test	Group	Max. possible score	Mean	S.D.
DAT	F	50	36.32	7.12
	S	50	35.72	6.39
NAO	F	30	10.96	4.14
	S	30	11.40	4.17
Inference	F	20	8.79	4.30
	S	20	8.97	3.76
Figure Classification	F	224	93.17	34.34
	S	224	87.76	33.48
Learning (Total)	F	20	11.15	3.08
	S	20	11.48	3.60
Learn (Part I)	F	15	7.48	2.59
	S	15	8.06	3.07
Learn (Part II)	F	5	3.68	.94
	S	5	3.42	.98
Retention[b]	F	19	10.45	2.68
	S	19	10.66	2.97

[a]The N for F group was 106 and N for S group was 102.

[b]The retention test was constructed parallel to the learning test, but due to a typing error, one of the items had no correct answer. Therefore there were only 19 items scored on the retention test.

Table 2

Reliability of Aptitude and Criterion Measures[a]

Test	Reliability
Abstract Reasoning	.92
NAO	.76
Inference	.72
Figure Classification[b]	
Criterion	

[a]KR-20 reliabilities are reported.

[b]Figure Classification measures were hand-scored and no reliabilities were obtained.

[c]Due to experimenter error criterion reliabilities were not available.

Table 3

Correlation Coefficients Between Groups
on Same Measures

Tests	Learning Part I		Learning Part II		Total Learning		Retention	
	F	S	F	S	F	S	F	S
1. Abstract Reasoning (DAT)	.24	.32	.11	.27	.24	.35	.23	.37
2. Figure Classification	.37	.31	.22	.16	.37	.31	.18	.14
3. Nec. Arith. Opns. (NAO)	.22	.34	.27	.16	.27	.33	.34	.39
4. Inference	.32	.42	.48	.25	.42	.42	.50	.56

Table 4

Information Pertaining To the Homogeneity of Regression Tests

Aptitudes Measures Used	Criterion Test	F-value	Probability value
Abstract Reasoning (Figural) Nec. Arith. Opns. (Symbolic)	Learning (Total)	.40	.68
Abstract Reasoning (Figural) Inference (Symbolic)	Learning (Total)	.73	.49
Figure Classification (Figural) Nec. Arith. Opns. (Symbolic)	Learning (Total)	.67	.52
Figure Classification (Figural) Inference (Symbolic)	Learning (Total)	.40	.68
Abstract Reasoning (Figural) Nec. Arith. Opns. (Symbolic)	Learning (Part I)	.45	.64
Abstract Reasoning (Figural) Inference (Symbolic)	Learning (Part I)	1.14	.32
Figure Classification (Figural) Inference (Symbolic)	Learning (Part I)	1.01	.37
Figure Classification (Figural) Nec. Arith. Opns. (Symbolic)	Learning (Part I)	1.25	.29
Abstract Reasoning (Figural) Nec. Arith. Opns. (Symbolic)	Learning (Part II)	1.50	.23
Abstract Reasoning (Figural) Inference (Symbolic)	Learning (Part II)	2.17	.12
Figure Classification (Figural) Inference (Symbolic)	Learning (Part II)	1.20	.30
Figure Classification (Figural) Nec. Arith. Opns. (Symbolic)	Learning (Part II)	.19	.83
Abstract Reasoning (Figural) Nec. Arith. Opns. (Symbolic)	Retention	.36	.70

Table 4 (cont'd)

Information Pertaining To the Homogeneity of Regression Tests

Aptitudes Measures Used	Criterion Test	F-value	Probability value
Abstract Reasoning (Figural) Inference (Symbolic)	Retention	1.20	.30
Figure Classification (Figural) Nec. Arith. Opns. (Symbolic)	Retention	.25	.79
Figure Classification (Figural) Inference (Symbolic)	Retention	1.58	.21